

## **APPENDIX B – JSC MEASURED DATA**

### **USCG AIS EMISSION SPECTRUM MEASUREMENTS**

#### **Objective**

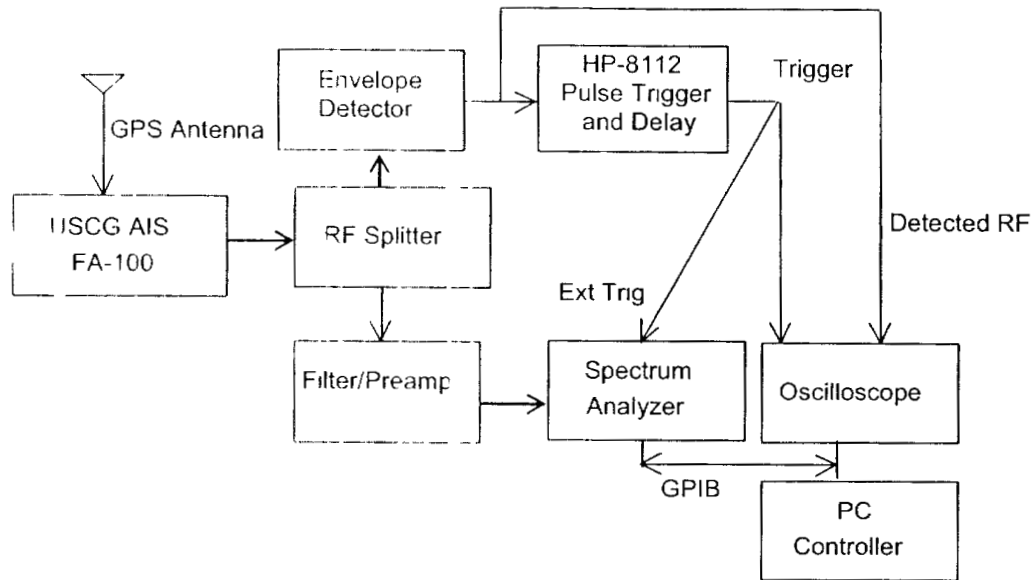
- Characterize the Furuno Universal AIS FA-100 transponder spectral emissions
- Examine the Ross DSC 500 audio output as the FA-100 transmits

#### **Methodology**

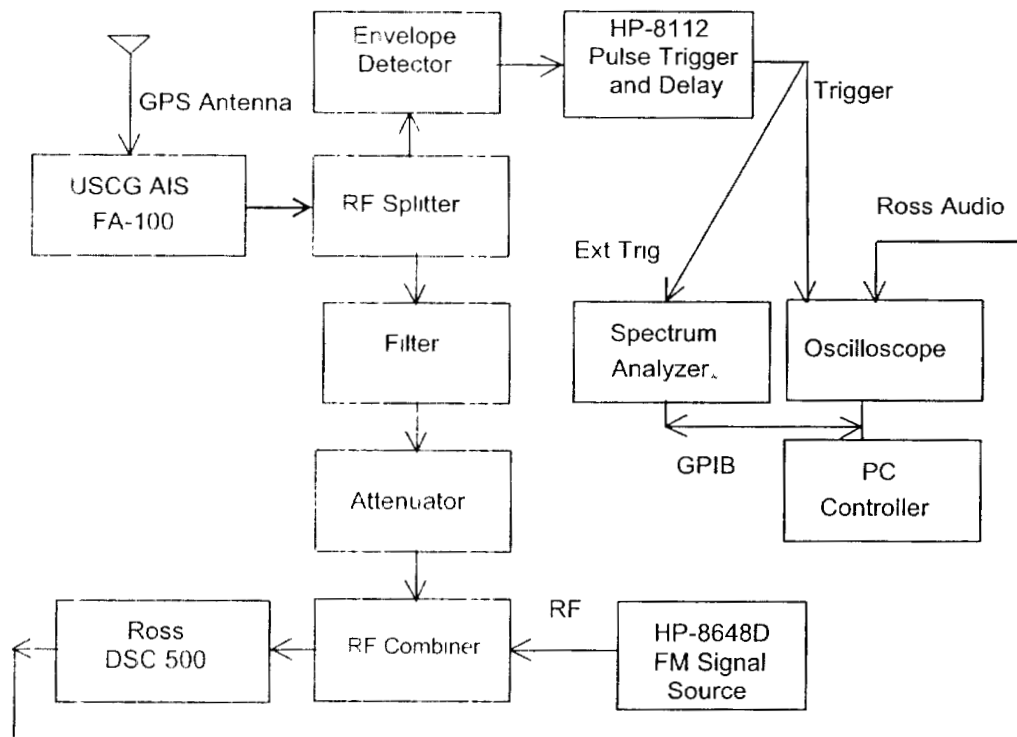
- Measure the emission during and between pulses
- Measure in-band, out-of-band, close-up, and broadband emissions
- Measure the DSC 500 audio output in the presence of FA-100 signals

#### **Procedure Summary**

- Design interfacing circuits between the transmitter/receiver and the measurement equipment – see block diagrams in Figures B-1 and B-2
- Mount the Furuno GPS antenna on the roof and connect it to the FA-100 GPS antenna port
- Initialize the FA-100 with proper maritime mobile service identity (MMSI) and ship static parameters
- Synchronize the FA-100 transmission bursts to the measurement equipment
- Set the FA-100, DSC 500, and measurement equipment operating parameters – see Table B-1
- Measure/record broadband and close-in emission spectrum on Furuno Channels 2087 and 2088 (with an emphasis on a 10-kHz bandwidth)
- Measure/record audio levels with the DSC 500 on channel 87
- Measure interfacing circuit gain/loss for calibration
- Provide analyses results



**Figure B-1. FA-100 Emission Spectrum Block Diagram**



**Figure B-2. FA-100 to DSC 500 Audio Sample - Block Diagram**

**Table B-1. Measurement Parameters - Summary and Commentary**

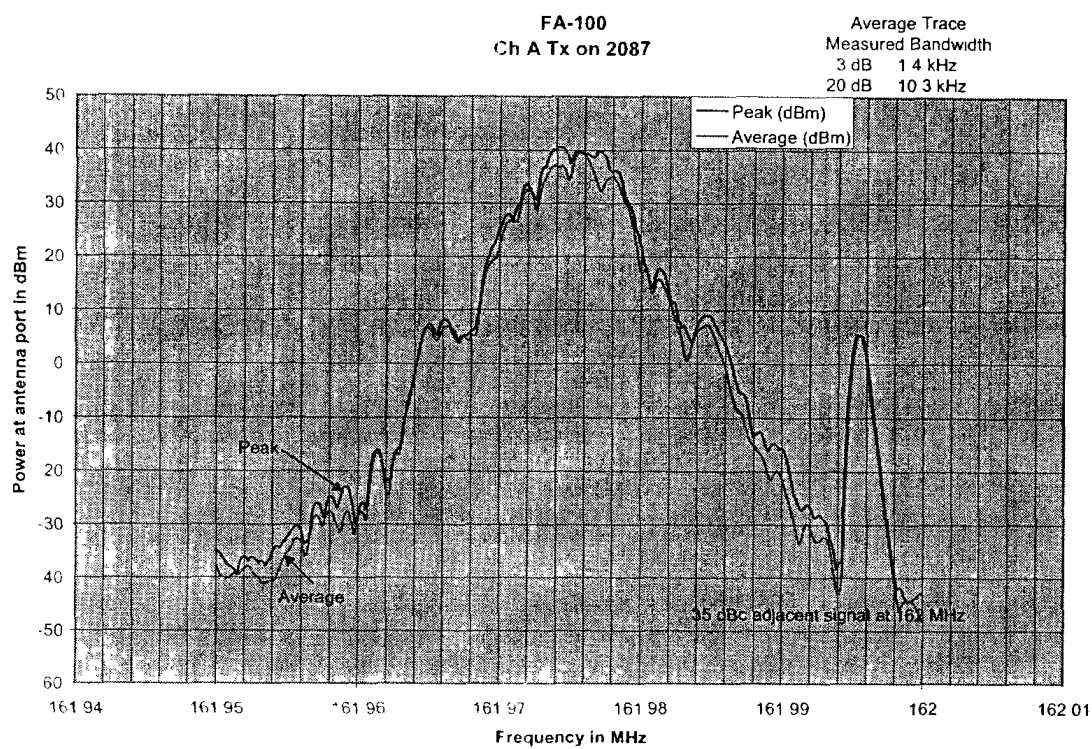
Figure	Start Freq (MHz)	Stop Freq (MHz)	RBW	SWP (MS)	REF (dBm)	Attn (dB)	Comment
3	161.950	162.000	1.5 kHz	27	-20	10	Transition Spur at 162 MHz
4	161.975	162.125	3 kHz	65	-20	10	Out-of-band emission spectrum
5	162	162.316	10 kHz	32	-40	0	Average trace level drops 17 dB during an on-to-off transition
6	161.778	162.278	10 kHz	30	0	10	Dual channel mode measurements
7	150	2000	3 MHz	56	0	10	Spurious at 414 MHz, Harmonics out to 5th
8	1575.17	1575.67	10 kHz	50	-20	10	Noise level at -112 dBm
9	161.725	162.225	10 kHz	30	0	20	Spurious emissions resulting from variable transmission times, times varied from 6.8 to 10 seconds
RBW – Receiver Bandwidth SWP – Sweep Time REF – Reference Level ATTN – Attenuation							

## Measurement Results

The results of measuring the FA-100 emission spectrum and the DSC 500 audio response in the presence of pulsed signals from the FA-100 are presented in the following set of figures.

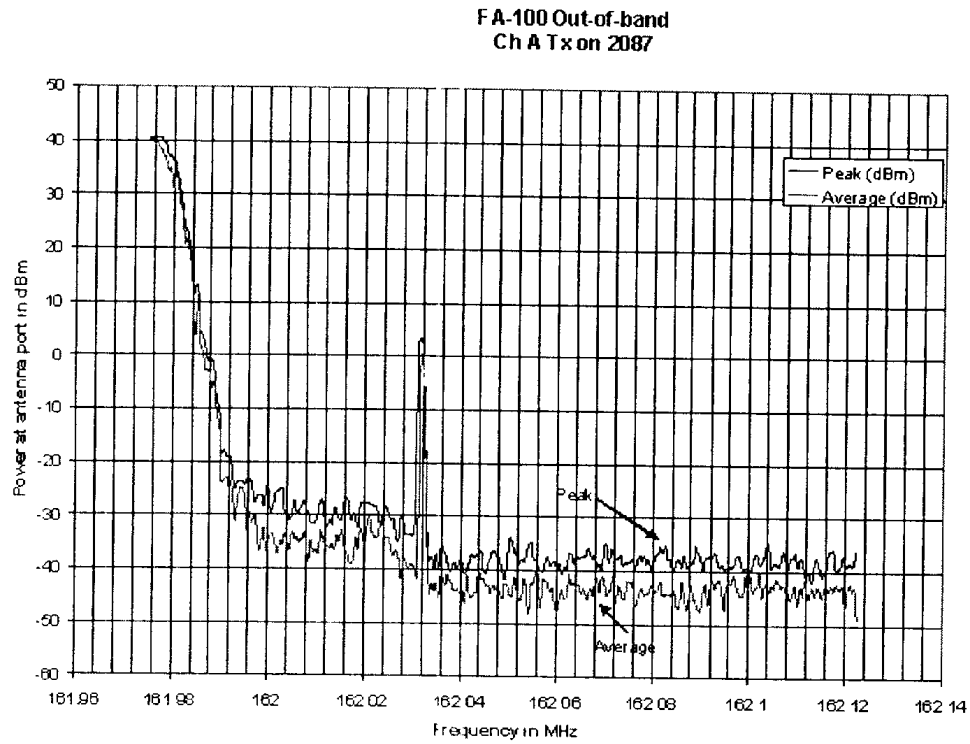
The FA-100 emission spectrum was measured with the spectrum analyzer in both the continuous and the triggered sweep modes. If the spectrum of this signal was accumulated for a longer period of time during the continuous test mode, the line spectrum components would have fully filled-in the spectrum. Emission spectra shown in Figures B-3 through B-8 were measured with the spectrum analyzer externally triggered from the detected pulse of the FA-100.

Figure B-3 shows the FA-100 transmitter peak and average spectrum integrated over five sweeps in a 1.5-kHz bandwidth. The spectrum shows a signal at 162 MHz that is down 35 dB down from carrier.



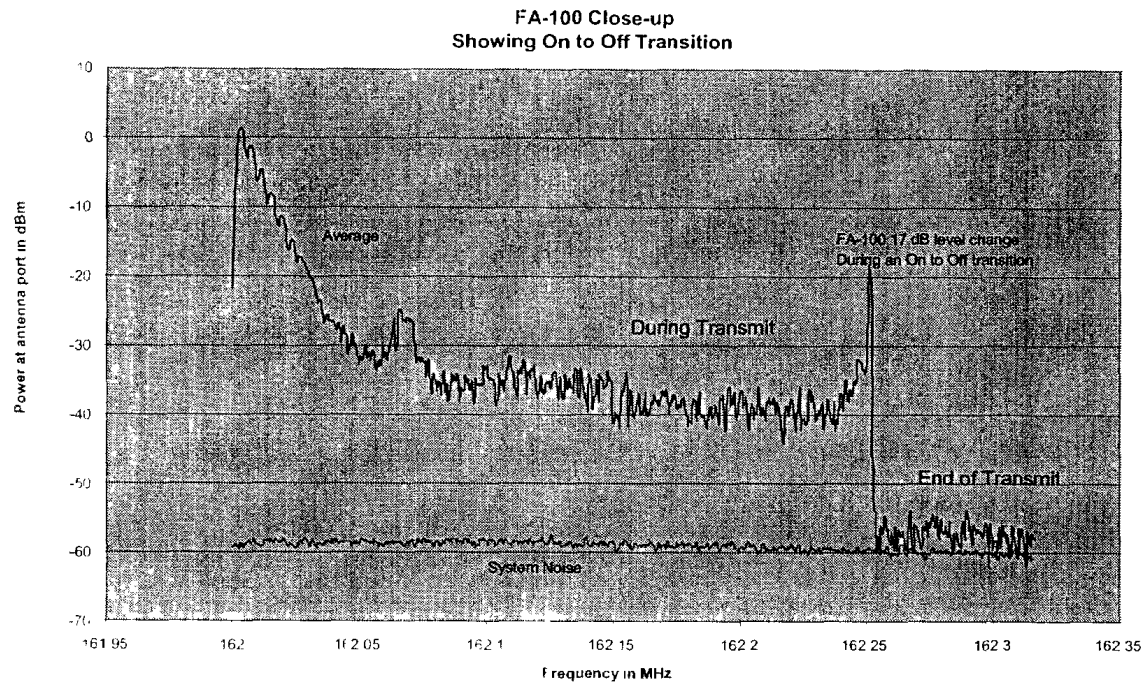
**Figure B-3. In-Band Single Channel Peak and Average Emission**

Figure B-4 shows the FA-100 transmitter peak and average spectrum integrated over five sweeps in a 3-kHz bandwidth.



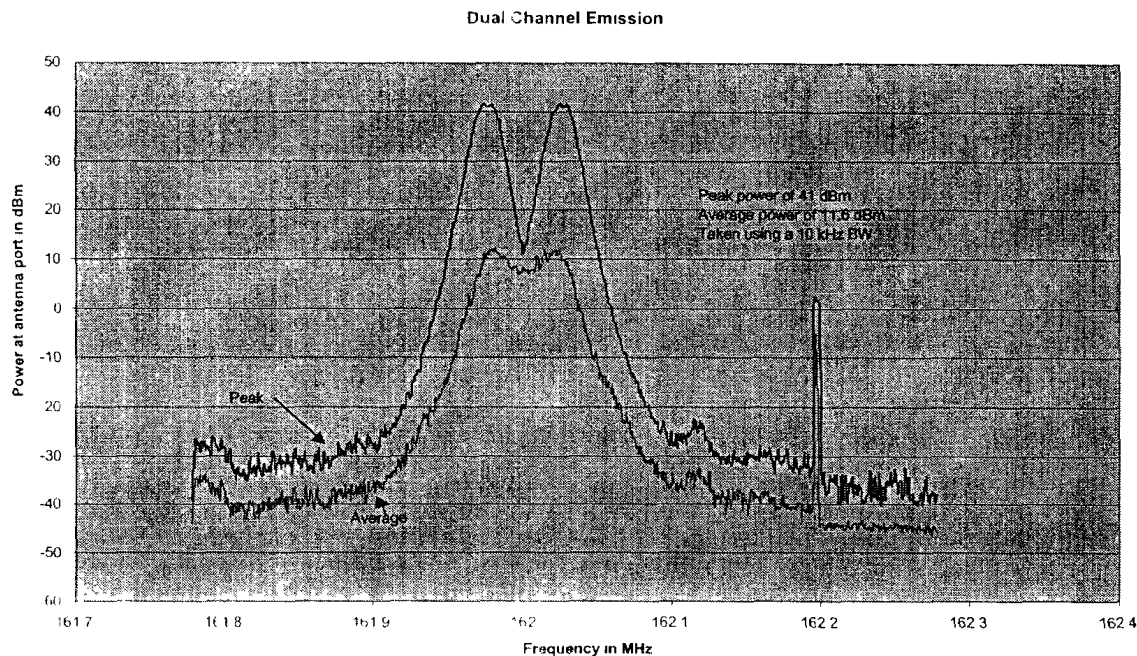
**Figure B-4. Out-of-Band Emission**

Figure B-5 shows a close-up of the spectrum on-to-off transition taking a 17-dB drop between 162.2 MHz and 162.25 MHz.



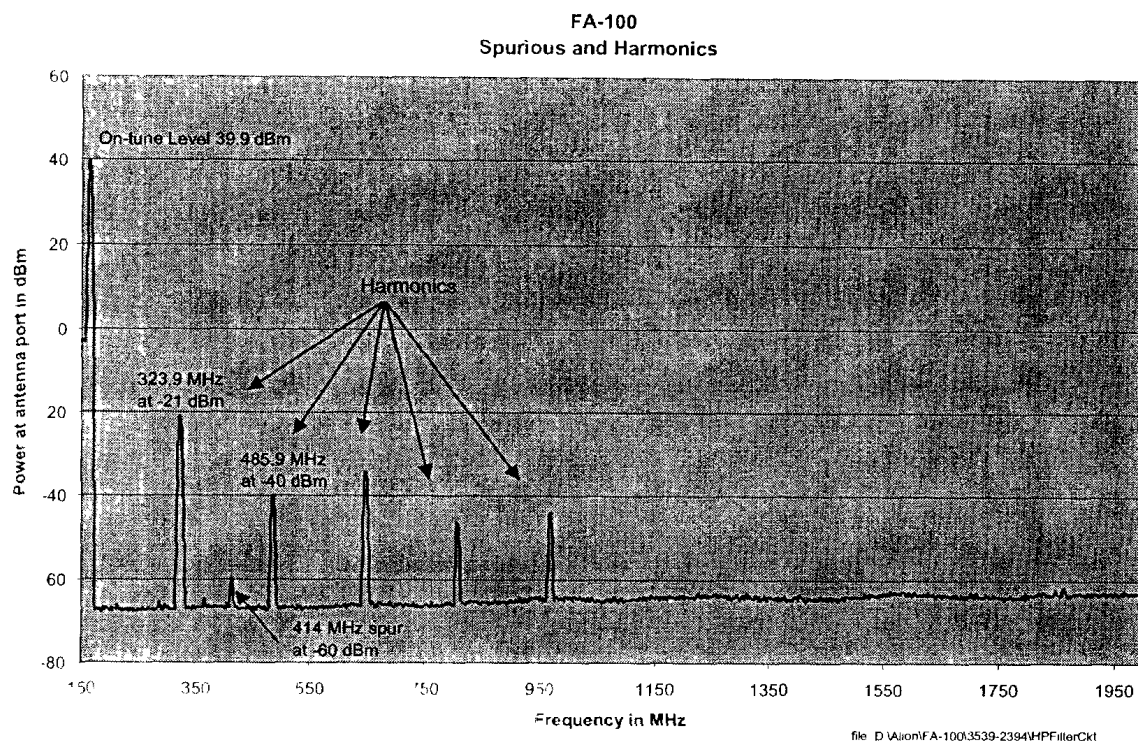
**Figure B-5. Close-Up Emission View of FA-100 Transition from On-to-Off State**

Figure B-6 shows the peak spectrum of two channels with equal power level, with one channel at a frequency 161.976 MHz and the second channel at 162.028 MHz. The average spectrum shows a 30-dB drop in signal level from the peak level, indicating that the channels do not transmit at the same time.



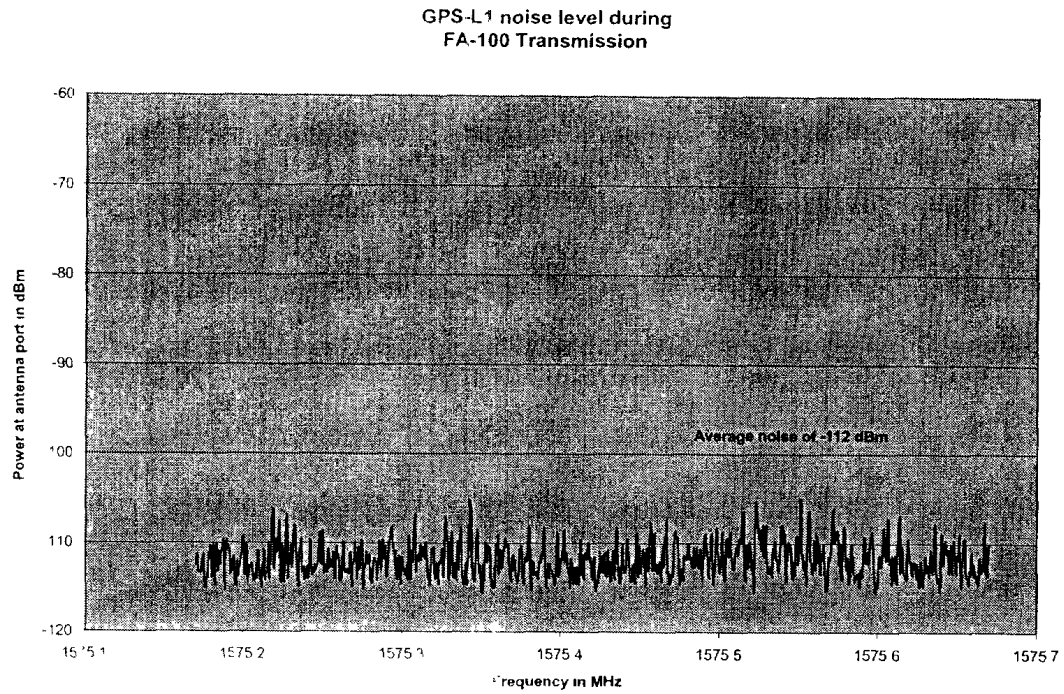
**Figure B-6. In-Band Dual Channel Peak and Average Emission**

Figure B-7 shows the harmonic and spurious spectrum of the FA-100 transmitter out to a frequency of 2000 MHz. The harmonic and spurious attenuations are at least 60 dB down from the carrier level.



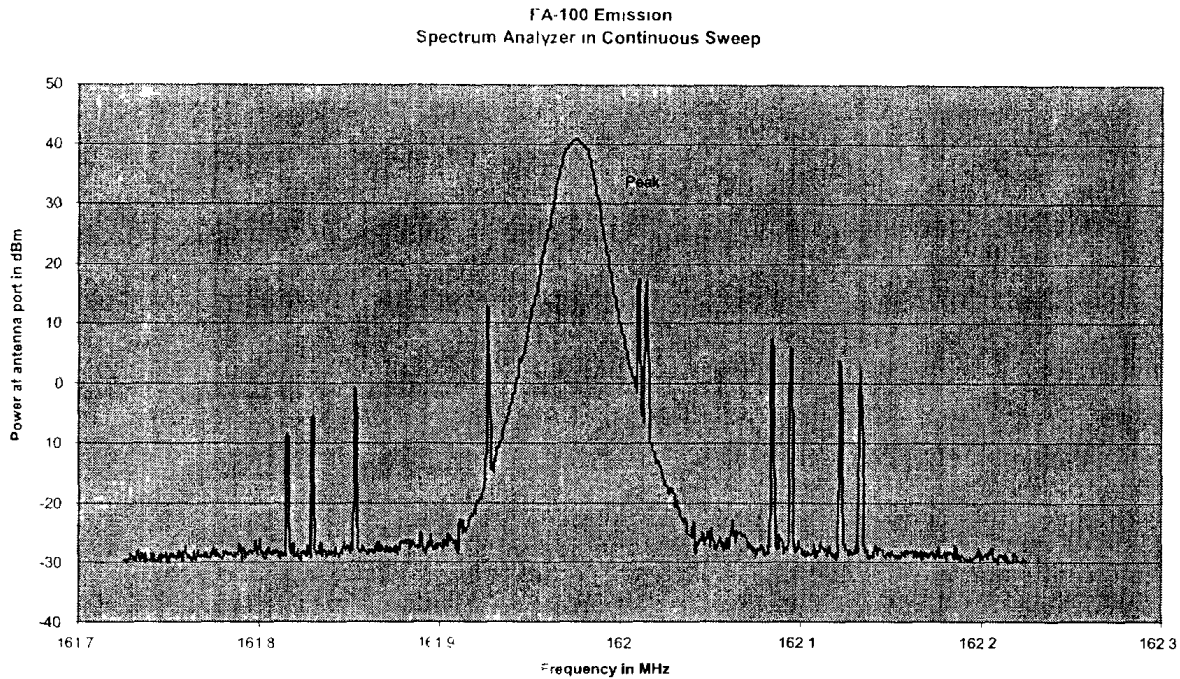
**Figure B-7. Broadband Harmonic and Spurious Emissions**

Figure B-8 shows the GPS-L1 frequency (out-of-band) noise level during FA-100 pulse transmission. The FA-100 noise fell below the measurement sensitivity of -112 dBm in a 10-kHz bandwidth.



**Figure B-8. Out-of-Band Emission Noise in the GPS-L1 Frequency**

Figure B-9 shows the continuous sweep mode spectrum of the pulsed signal from the FA-100.



**Figure B-9. Continuous Sweep (Non-Triggered) Emission Spectrum**

Figures B-10 through B-18 show time-domain plots taken with an oscilloscope. These plots capture the audio response of the DSC 500 VHF transceiver both on-tune and off-tune. Measurements were taken using the interference levels shown in Table B-2. The top trace shows FA-100 pulse on-and-off conditions. The bottom trace tracks the audio output of the DSC 500 during and between interfering pulses.

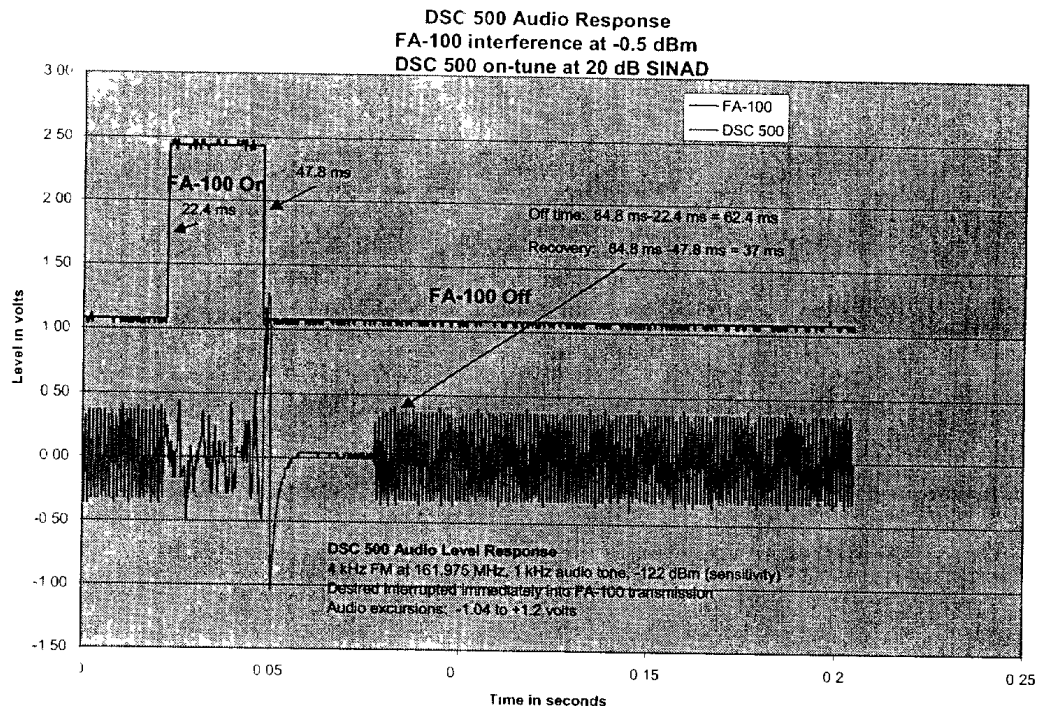


Figure B-10. DSC 500 Audio Response, FA-100 Interference at -0.5 dBm

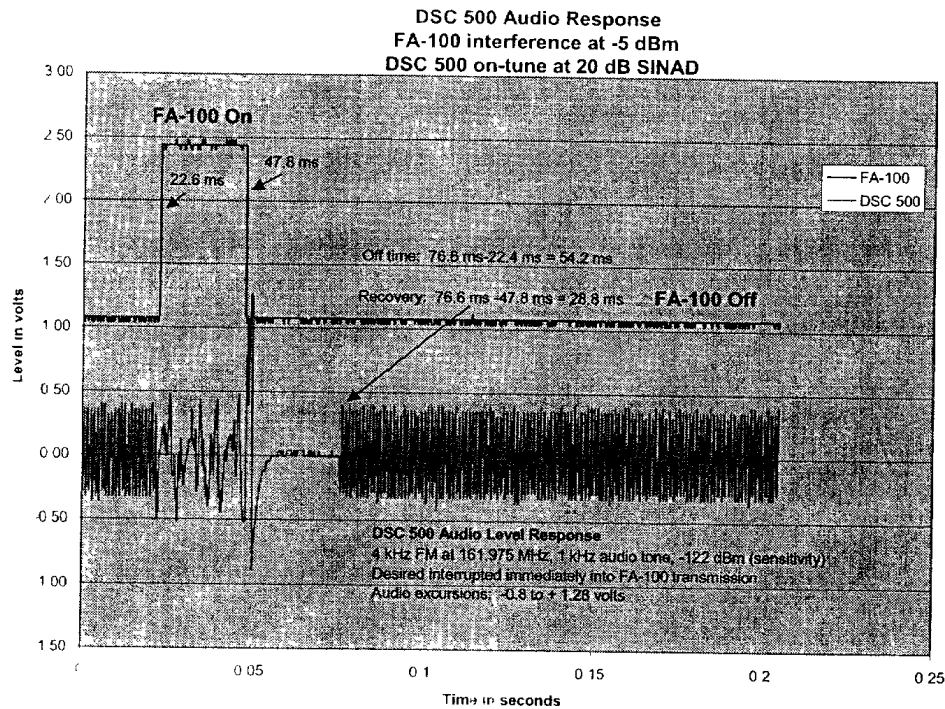


Figure B-11. DSC 500 Audio Response, FA-100 Interference at -5 dBm

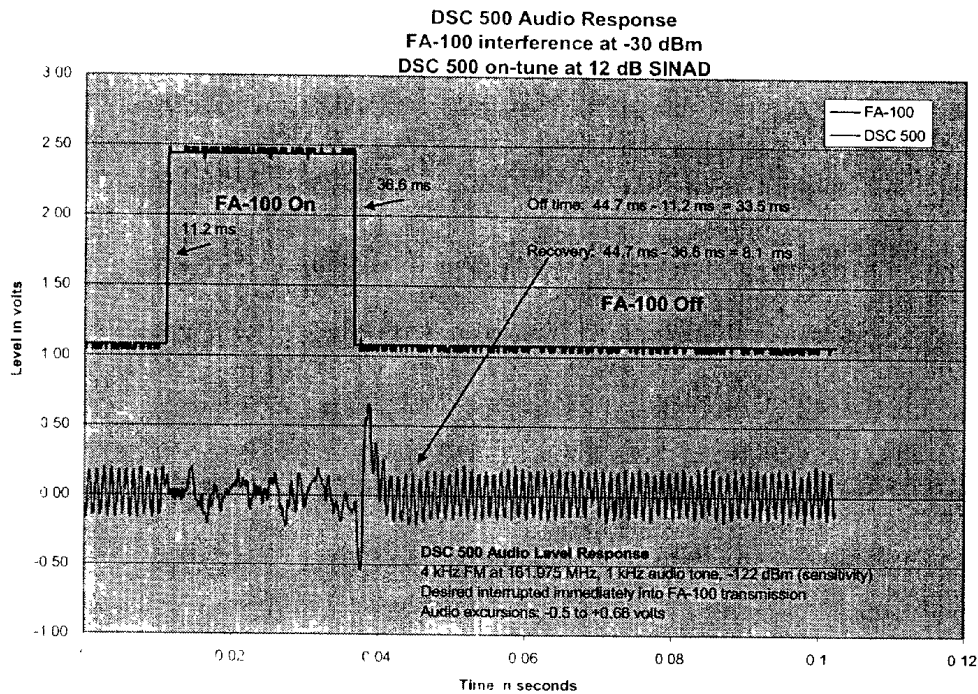


Figure B-12. DSC 500 Audio Response, FA-100 Interference at -30 dBm

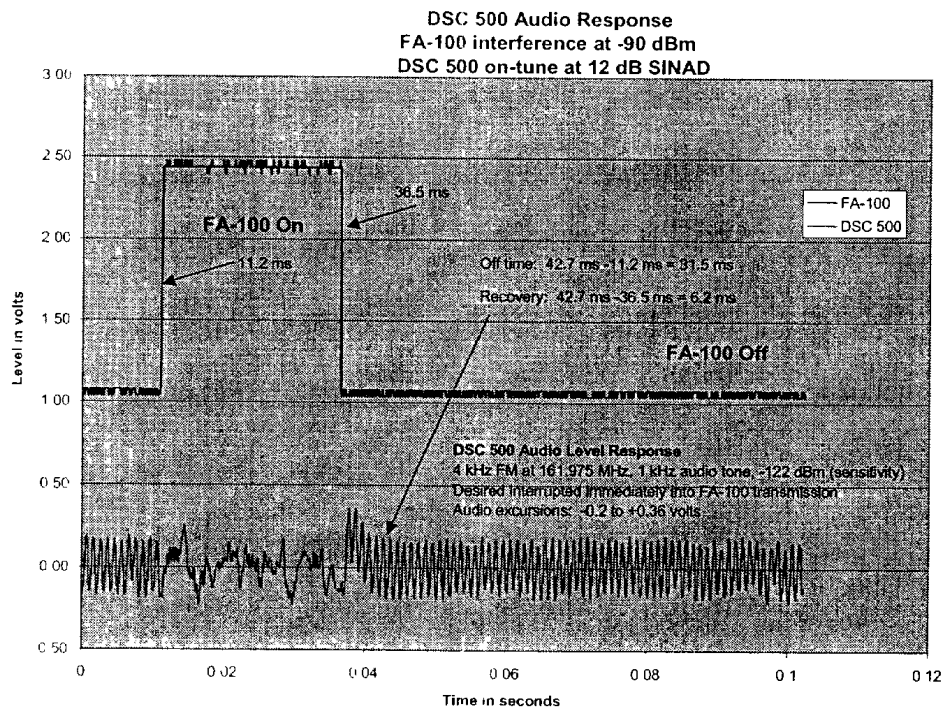
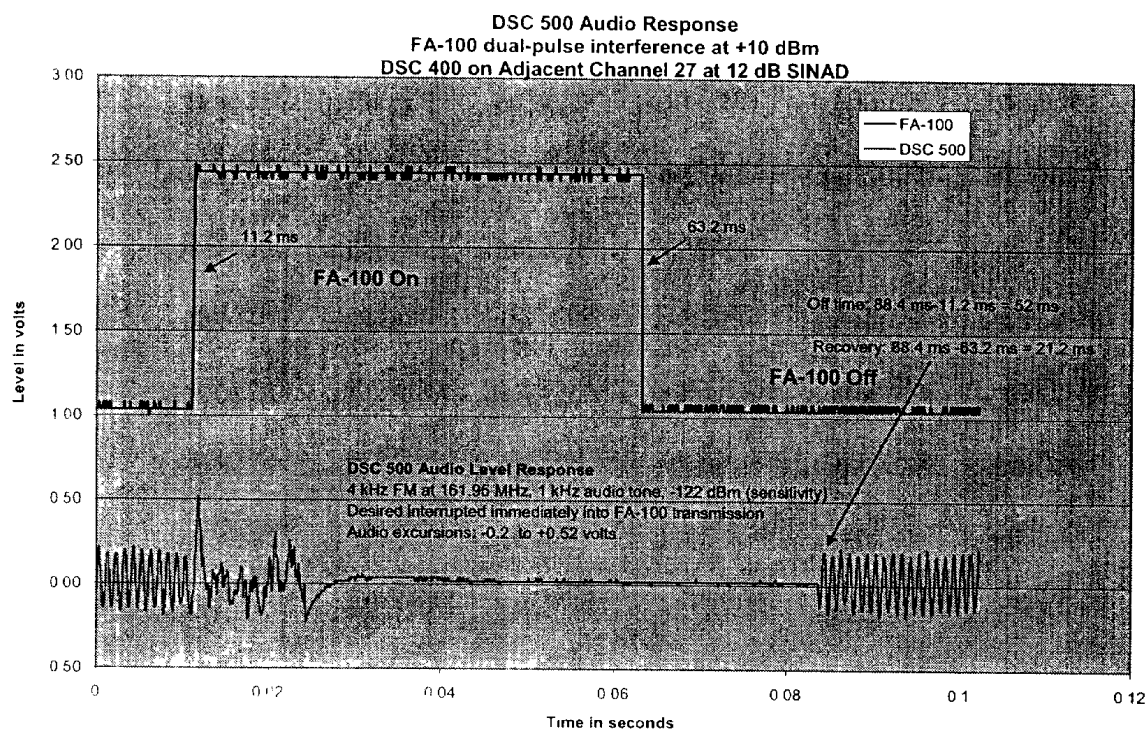
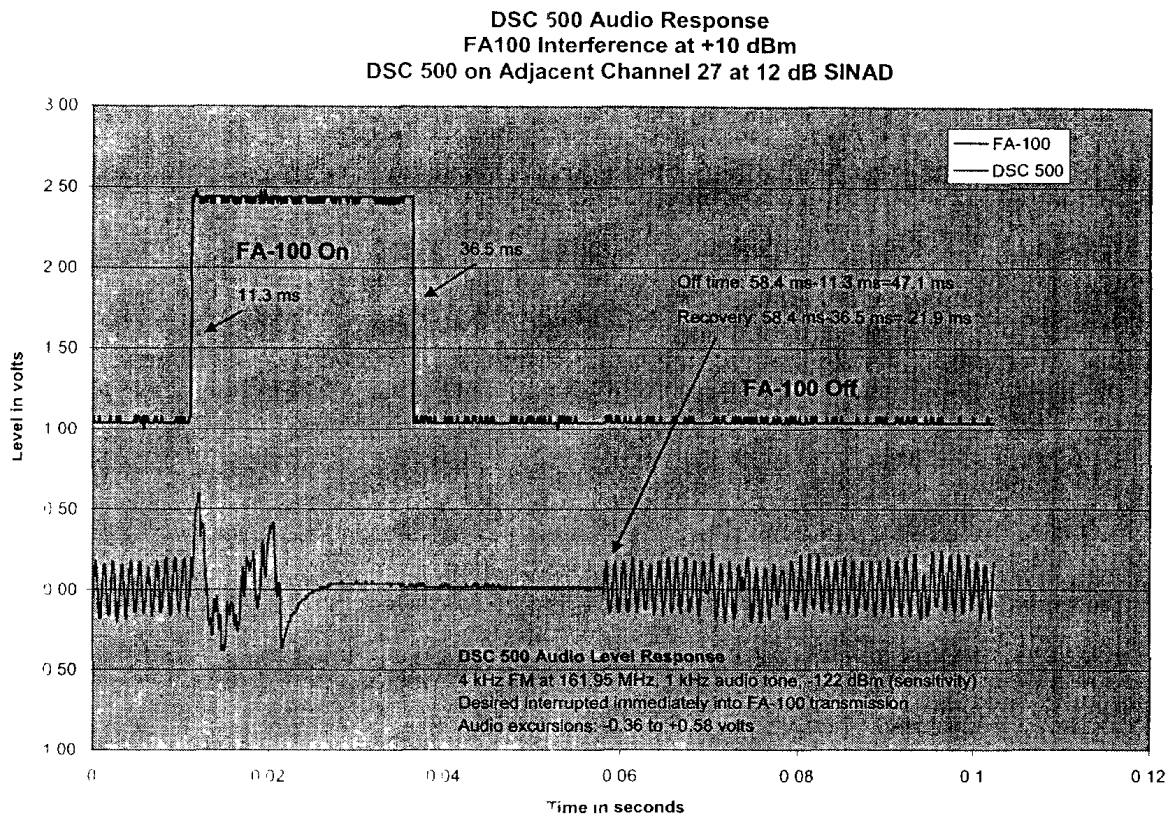


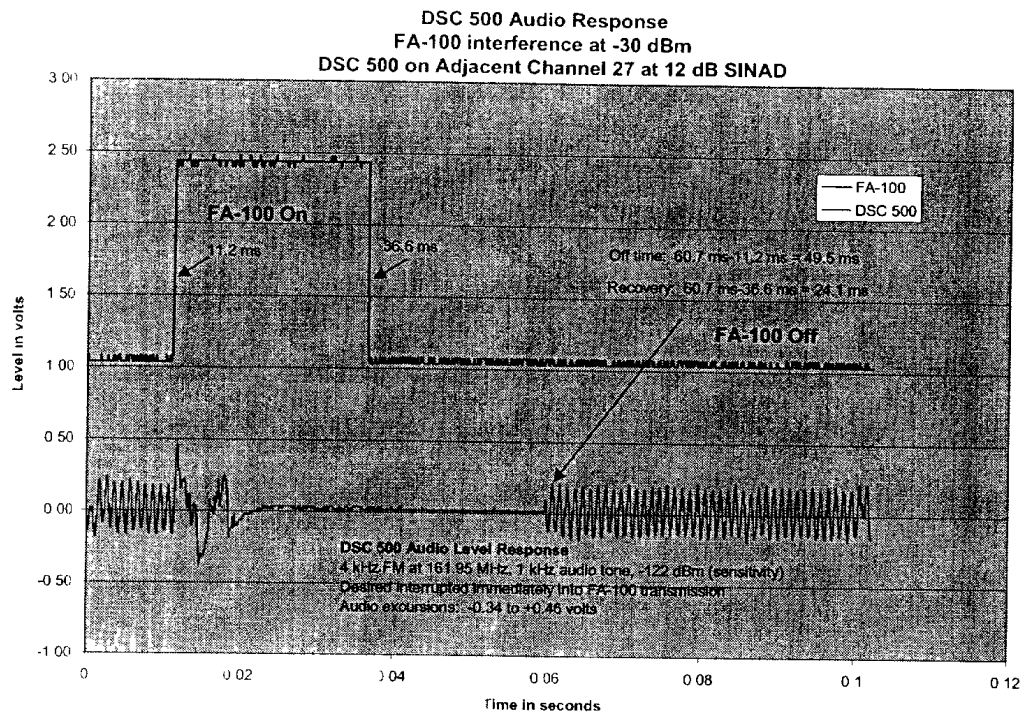
Figure B-13. DSC 500 Audio Response, FA-100 Interference at -90 dBm



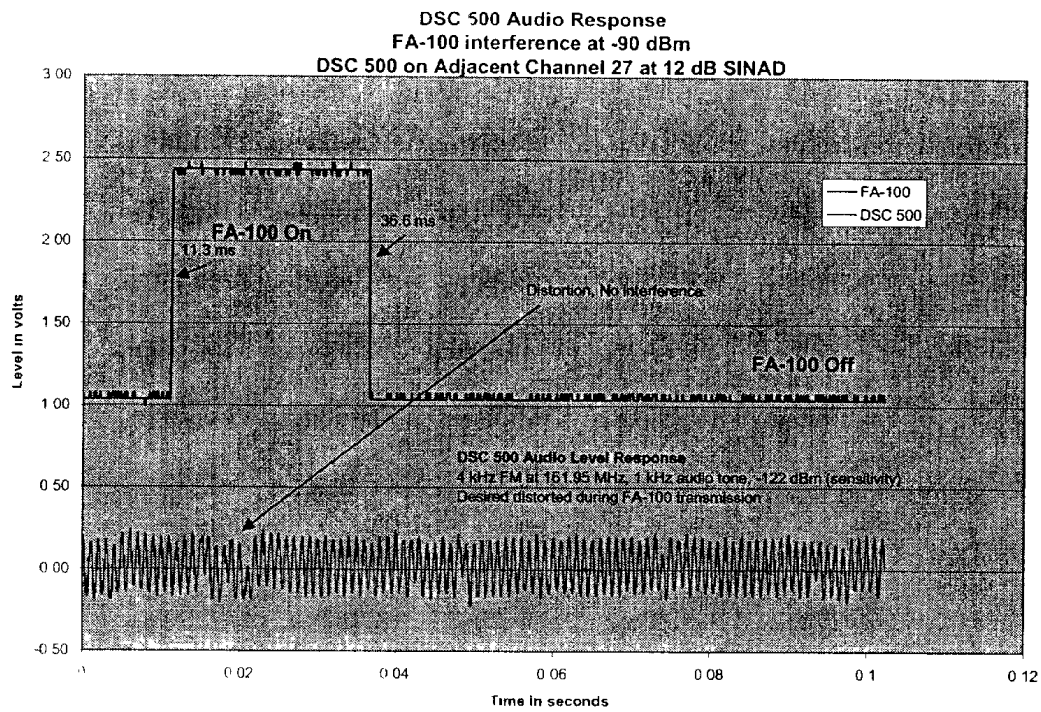
**Figure B-14. DSC 500 63.2 ms Audio Response, FA-100 Interference at +10 dBm**



**Figure B-15. DSC 500 36.5 ms Audio Response, FA-100 Interference at +10 dBm**



**Figure B-16. DSC 500 Audio Response, FA-100 Interference at -30 dBm**



**Figure B- 17. DSC 500 Audio Response, FA-100 Interference at -90 dBm**

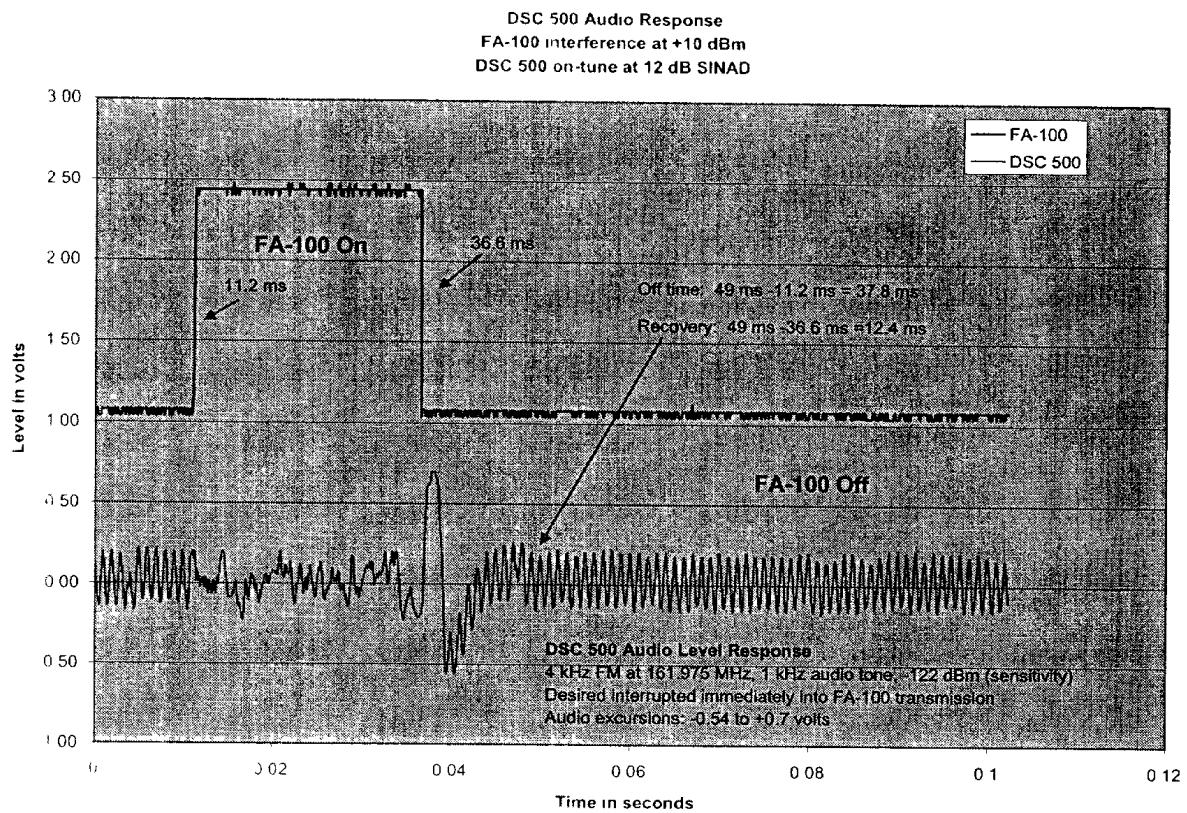


Figure B-18. DSC 500 Audio Response, FA-100 Interference at +10 dBm

**Table B-2. Furuno FA-100/Ross DSC 500 Measurement Parameters**

Figure	Furuno FA-100			Ross DSC 500			
	Interference Level (dBm)	Mode	Pulsewidth (ms)	SINAD (dB)	Audio Off Time (ms)	Recovery Time (ms)	Channel
10	-0.5	Single Pulse	25.4	20	62.4	37	87 on-tune
11	-5	Single Pulse	25.2	20	54.0	28.8	87 on-tune
12	-30	Single Pulse	25.4	12	33.5	8.1	87 on-tune
13	-90	Single Pulse	25.3	12	31.5	6.2	87 on-tune
14	10	Dual Pulse	52.0	12	52.0	21.2	27 (adj ch)
15	10	Single Pulse	25.2	12	47.1	21.9	27 (adj ch)
16	-30	Single Pulse	25.4	12	49.5	24.1	27 (adj ch)
17	-90	Single Pulse	25.3	12	000.0	No interference - some distortion	27 (adj ch)
18	10	Single Pulse	25.4	12	37.8	12.4	87 on-tune

## MEASUREMENT SUMMARY

### Peak Power Levels for the Furuno FA-100

The peak power levels shown in Figure B-6 for the Furuno FA-100 transmitter are summarized in Table B-3.

**Table B-3. FA-100 Peak Power Levels**

	Single Channel		Dual Channel	
	dBm	watts	dBm	watts
Peak	40.7	11.7	41.0	12.6

### Furuno FA-100 Harmonics

The frequency and power level of the Furuno FA-100 transmitter are shown in Table B-4.

**Table B-4. Harmonic Frequency and Power**

	Frequency (MHz)	Power (dBm)	Power (dBc)
Second	323.9	-21.0	61.0
Third	485.9	-40.0	80.0
Fourth	647.6	-34.0	74.0
Fifth	810.4	-47.5	87.5
Sixth	971.4	-44.0	84.0

### Out-of-Band Noise Measurement

The FA-100 out-of-band noise at the GPS-L1 frequency, fell below measurement sensitivity of -112 dBm in a 10-kHz bandwidth.

### DSC 500 Interference Due to FA-100 Pulses

The DSC 500 audio recovery response time and off-time varied as a function of the FA-100 pulse power, desired signal, signal + noise + distortion to noise + distortion (SINAD) ratio level; and channel separation. The recovery time varied from zero milliseconds (ms) with no interference up to 37 ms with interference

## APPENDIX C – INTERNATIONAL VHF MARITIME RADIO CHANNELS AND FREQUENCIES

Table C-1 is adapted from the *International Telecommunication Union Radio Regulations Appendix 18*, including changes adopted by the 2000 World Radio Conference (WRC). Transmission on frequencies or channels shown in **bold** are not allowed within US territorial waters, but are allowed on the high seas and in most other countries. Note that a maritime radio operating in the international mode on a channel in which the ship station frequency is shown in ***bold italics*** and where the coastal station frequency is shown in **bold** would not be able to communicate with a US coastal station. The large number of **bolded** channels and frequencies indicates the shortage of VHF maritime spectrum in the US compared to most other maritime countries. Finally, note also that changes made by WRC 97 shown in *italics* have not yet been approved

**Table C-1. Table of Transmitting Frequencies in the VHF Maritime Mobile**

Channel Number	Note	Transmitting Frequencies (MHz)		Channel Use			
		Ship Stations	Coastal Stations	Intership	Port Operations and Ship Movement		Public Correspondence
					Single Frequency	Two Frequency	
60		156.025	160.625			x	x
01		156.050	160.650			x	x
61	m, o	156.075	160.675			x	x
02	m, o	156.100	160.700			x	x
62	m, o	156.125	160.725			x	x
03	m, o	156.150	160.750			x	x
63	m, o	156.175	160.775			x	x
04	m, o	156.200	160.800			x	x
64	m, o	156.225	160.825			x	x
05	m, o	156.250	160.850			x	x
65	m, o	156.275	160.875			x	x
06	f	156.300		x			
66		156.325	160.925			x	x
07		156.350	160.950			x	x
67	h	156.375	156.375	x	x		
08		156.400		x			
68		156.425	156.425		x		

**Table C-1. Table of Transmitting Frequencies in the VHF Maritime Mobile**

Channel Number	Note	Transmitting Frequencies (MHz)		Channel Use			
		Ship Stations	Coastal Stations	Intership	Port Operations and Ship Movement		Public Correspondence
					Single Frequency	Two Frequency	
09	i	156.450	156.450	x	x		
69		156.475	156.475	x	x		
10	h	156.500	156.500	x	x		
70	j	156.525	156.525	Digital selective calling for distress, safety, and calling			
11		156.550	156.550		x		
71		156.575	156.575		x		
12		156.600	156.600		x		
72	i	156.625		x			
13	k	156.650	156.650	x	x		
73	h, i	156.675	156.675	x	x		
14		156.700	156.700		x		
74		156.725	156.725		x		
15	g	<b>156.750</b>	156.750	x	x		
<b>75</b>	n	<b>156.775</b>			x		
16		156.800	156.800	distress, safety, and calling			
<b>76</b>	n	<b>156.825</b>			x		
17	g	156.850	156.850	x	x		
77		156.875		x			
18	m	156.900	<b>161.500</b>		x	x	x
78		156.925	<b>161.525</b>			x	x
19		156.950	<b>161.550</b>			x	x
79		156.975	<b>161.575</b>			x	x
20		157.000	<b>161.600</b>			x	x
80		157.025	<b>161.625</b>			x	x
21		157.050	<b>161.650</b>			x	x
81		157.075	<b>161.675</b>			x	x
22	m	157.100	<b>161.700</b>			x	x
82	m, o	157.125	<b>161.725</b>		x	x	x
23	m, o	157.150	<b>161.750</b>			x	x
83	m, o	157.175	<b>161.775</b>		x	x	x
24	m, o	157.200	161.800			x	x
84	m, o	157.225	161.825		x	x	x
25	m, o	157.250	161.850			x	x

**Table C-1. Table of Transmitting Frequencies in the VHF Maritime Mobile**

Channel Number	Note	Transmitting Frequencies (MHz)		Channel Use			
		Ship Stations	Coastal Stations	Intership	Port Operations and Ship Movement		Public Correspondence
					Single Frequency	Two Frequency	
85	m, o	157.275	161.875		x	x	x
26	m, o	157.300	161.900			x	x
86	m, o	157.325	161.925		x	x	x
27		157.350	161.950			x	x
87		<b>157.375</b>			x		
28		157.400	162.000			x	x
88		157.425			x		
AIS 1	I	161 975	161 975				
AIS 2	I	162 025	162.025				

**General Notes for Table C-1**

- a. Administrations may designate frequencies in the intership, port operations, and ship movement services for use by light aircraft and helicopters to communicate with ships or participating coast stations in predominantly maritime support operations under the conditions specified in Nos **S51.69**, **S51.73**, **S51.74**, **S51.75**, **S51.76**, **S51.77** and **S51.78**. However, the use of the channels that are shared with PC shall be subject to prior agreement between administrations that are interested and affected administrations.
- b. The channels of the present Appendix [APP 18] with the exception of channels 06, 13, 15, 16, 17, 70, 75 and 76, may also be used for high-speed data and facsimile transmissions, subject to special arrangement between interested and affected administrations.
- c. The channels of the present Appendix [APP 18] but preferably channel 28 and with exception of channels 06, 13, 15, 16, 17, 70, 75 and 76, may be used for direct-printing telegraphy and data transmission, subject to special arrangement between interested and affected administrations.
- d. The frequencies in this table may also be used for radio communications on inland waterways in accordance with the conditions specified in No. **S5.226**.

- e Administrations having an urgent need to reduce local congestion may apply 12.5 kHz channel interleaving on a noninterference basis to 25-kHz channels, provided the following conditions are met:
  - 1) Recommendation ITU-R M.1084-2 shall be taken into account when changing to 12.5 kHz channels;
  - 2) This application shall not affect the 25-kHz channels, listed in Appendix S18, for maritime mobile distress and safety frequencies, especially the channels 06, 13, 15, 16, 17, and 70, nor the technical characteristics mentioned in Recommendation ITU-R M.489-2 for these channels;
  - 3) Implementation of 12.5 kHz channel interleaving and consequential national requirements shall be subject to prior agreement between the administrations implementing these changes and administrations whose ship station or services may be affected.

### Specific Notes for Table C-1

- i The frequency 156.300 MHz (channel 06) (see Appendix S13, Appendix S15 and Appendix S51.79) may also be used for communication between ship stations and aircraft stations engaged in coordinated search and rescue operations. Ship stations shall avoid harmful interference to such communications on channel 06 as well as communications between aircraft stations, ice-breakers, and assisted ships during ice seasons.
- g Channels 15 and 17 may also be used for onboard communications, provided the effective radiated power does not exceed 1 W, and subject to the national regulations of the administration concerned when these channels are used in its territorial waters.
- h Within the European Maritime Area and in Canada, these frequencies (channels 10, 67, 73) may also be used, if required by the individual administrations concerned, for communication between ship stations, aircraft stations, and participating land stations engaged in coordinated search and rescue and anti-pollution operations in local areas, under the conditions specified in Nos. S51.69, S51.73, S51.74, S51.75, S51.76, S51.77, and S51.78.
- i The preferred first three frequencies for the purpose indicated in note a. are 156.450 MHz (channel 09), 156.625 MHz (channel 72) and 156.675 MHz (channel 73).
- j This channel (70) is to be used exclusively for digital selective calling for distress, safety, and calling.
- k Channel 13 is designated for use on a worldwide basis as a navigation safety communication channel, primarily for intership navigation safety communications. It may also be used for the ship movement and port operations service subject to the national regulations of the administrations concerned

- l These channels will be used for an automatic ship identification and surveillance system capable of providing worldwide operation on high seas, unless other frequencies are designated on a regional basis for this purpose
- m These channels may be operated as a single frequency channel, subject to special arrangement between interested or affected administrations. (WRC-2000)
- n The use of these channels should be restricted to navigation-related communications only, and all precautions should be taken to avoid harmful interference to channel 16, e.g., by limiting the output power to 1 W or by geographical separation.
- o These channels may be used to provide bands for initial testing and possibly, in the future, for introducing new technologies, subject to special arrangement between interested or affected administrations. Stations using these channels or bands for testing or introducing new technologies shall neither cause harmful interference to, nor claim protection from, other stations operating in accordance with Article 5.

## APPENDIX D – INTERFERENCE POWER LEVELS AT THE PC RECEIVER INPUT (VOICE MODE)

The equations used for calculating the  $P_{\text{ino}}$  distributions for the various interaction modes are presented in this appendix. Many of the parameters in these equations are stored in the COSAM Equipment Parameter File (EPF).

### Transmitter Adjacent Signal (TAS)

The power spectral density  $S_p$  is obtained from the transmitter power spectral density curve found in the EPF transmitter record. The curve is symmetric about  $\Delta f = 0$ . The TAS calculation should be skipped if the frequencies are cochannel. The mean  $P_{\text{ino}}$  for the transmitter adjacent-signal interaction is given by:

$$P_{\text{ino}} = S_p (\Delta f) + 10 \log (BW_r) + G_t + G_r - L_s - L_p \quad (\text{D-1})$$

where

$P_{\text{ino}}$	=	mean equivalent on-tune interference power level, in dBm
$S_p$	=	mean power spectral density, in dBm/MHz
$\Delta f$	=	$F_r - F_t$ , in MHz
$F_r$	=	tuned frequency of receiver, in MHz
$F_t$	=	tuned frequency of transmitter, in MHz
$BW_r$	=	receiver RF bandwidth, in MHz
$G_t$	=	transmitter antenna gain, in dBi
$G_r$	=	receiver antenna gain, in dBi
$L_s$	=	system losses, in dB
$L_p$	=	mean coupling loss from AIS transmitter antenna to PC receiver antenna, in dB

In these equations, the variable  $L_p$  represents the antenna-to-antenna coupling loss.

The TAS  $P_{\text{ino}}$  power levels in the PC receiver 3-dB bandwidth are shown in Table D-1.

**Table D-1. TAS AIS Interference Power Levels at the PC Receiver Input-Voice and Data Modes**

$S_p$ (dBm/MHz)	10 Log (BW <sub>r</sub> ) (dB)	$G_t$ (dBi)	$G_r$ (dBi)	$L_s$ (dB)	$L_p$ (dB)	Horizontal Antenna Separation (feet)	Delta f (kHz)	$P_{ino}$ (dBm)
-19.81	-18.9	2.1	2.1	1	26.3	10	25	-61.8
-20.81	-18.9	2.1	2.1	1	26.3	10	50	-62.8
-21.81	-18.9	2.1	2.1	1	26.3	10	75	-63.8
-19.81	-18.9	2.1	2.1	1	66.4	1,000	25	-101.9
-20.81	-18.9	2.1	2.1	1	66.4	1,000	50	-102.9
-21.81	-18.9	2.1	2.1	1	66.4	1,000	75	-103.9
-19.81	-18.9	2.1	2.1	1	97.4	10,000	25	-132.9
-20.81	-18.9	2.1	2.1	1	97.4	10,000	50	-133.9
-21.81	-18.9	2.1	2.1	1	97.4	10,000	75	-134.9

**Receiver Adjacent Signal 1 (RAS1)**

The mean receiver rejection (Beff) is obtained from the receiver rejection curve found in the EPF receiver record. The curve is symmetric about delta f = 0. The mean  $P_{ino}$  for the receiver adjacent-signal interaction is given by:

$$P_{ino} = P_t + G_t + G_r - L_s - L_p - \text{Beff}(\Delta f) \quad (\text{D-2})$$

where

$P_{ino}$  = mean equivalent on-tune interference power level, in dBm

$P_t$  = mean peak output power of AIS transmitter, in dBm

Beff (Delta f) = mean rejection of undesired power by PC receiver, in dB

and other terms are as defined previously.

The RAS1  $P_{ino}$  power levels at the PC receiver front end are shown in Table D-2.

Table D-2. AIS RAS1 Interference Power Levels at the PC Receiver Input-Voice Mode

$P_i$ (dBm)	$G_t$ (dBi)	$G_r$ (dBi)	$L_s$ (dB)	$L_p$ (dB)	Voice Mode Beff (dB)	Horizontal Antenna Separation (feet)	Delta f (kHz)	$P_{ino}$ (dBm)
41	2.1	2.1	1	26.3	62	10	25	-44.1
41	2.1	2.1	1	26.3	72	10	50	-54.1
41	2.1	2.1	1	26.3	77	10	75	-59.1
41	2.1	2.1	1	66.4	62	1,000	25	-84.2
41	2.1	2.1	1	66.4	72	1,000	50	-94.2
41	2.1	2.1	1	66.4	77	1,000	75	-99.2
41	2.1	2.1	1	97.4	62	10,000	25	-115.2
41	2.1	2.1	1	97.4	72	10,000	50	-125.2
41	2.1	2.1	1	97.4	77	10,000	75	-130.2

## APPENDIX E – INTERFERENCE POWER LEVELS AT THE PC RECEIVER INPUT (DATA MODE)

The equations used for calculating the  $P_{ino}$  distributions for the various interaction modes are presented in this appendix. Many of the parameters in these equations are stored in the EPF.

### Transmitter Adjacent Signal

The mean  $P_{ino}$  interference power level received in the PC receiver 3-dB bandwidth in the voice mode is the same  $P_{ino}$  interference power levels received in the data mode. For the TAS  $P_{ino}$  interference power levels at the PC receiver input, refer to Table D-1.

### Receiver Adjacent Signal 1

$B_{eff}$  is obtained from the receiver rejection curve found in the EPF receiver record. The curve is symmetric about  $\Delta f = 0$ . The mean  $P_{ino}$  for the receiver adjacent-signal interaction with nonlinear effects is given by Equation D-2

The RAS1  $P_{ino}$  power levels at the PC receiver front end are shown in Table E-1.

**Table E-1. AIS RAS Interference Power Levels at the PC Receiver Input-Data Mode**

$P_{ino}$ (dBm)	$P_t$ (dBm)	$G_t$ (dBi)	$G_r$ (dBi)	$L_s$ (dB)	$L_p$ (dB)	Data Mode $B_{eff}$ (dB)	Horizontal Antenna Separation (feet)	Delta $f$ (kHz)
-52.1	41	2.1	2.1	1	26.3	70	10	25
-72.1	41	2.1	2.1	1	26.3	90	10	50
-74.3	41	2.1	2.1	1	26.3	92.2	10	75
-92.2	41	2.1	2.1	1	66.4	70	1,000	25
-112.2	41	2.1	2.1	1	66.4	90	1,000	50
-114.4	41	2.1	2.1	1	66.4	92.2	1,000	75
-123.2	41	2.1	2.1	1	97.4	70	10,000	25
-143.2	41	2.1	2.1	1	97.4	90	10,000	50
-145.4	41	2.1	2.1	1	97.4	92.2	10,000	75

**DISTRIBUTION LIST FOR  
EMC ANALYSIS OF UNIVERSAL AUTOMATIC IDENTIFICATION  
AND PUBLIC CORRESPONDENCE SYSTEMS IN  
THE MARITIME VHF BAND  
JSC-PR-04-007**

External

No. of Copies

US Coast Guard, Commandant (G-SCT-2) .....	1
Spectrum Management Division	
Attn. Mr. Joseph D. Hersey, Jr.	
2100 Second Street, SW	
Washington, DC 20593-0002	
US Coast Guard Headquarters (CG-62) .....	12
2100 Second Street, SW	
Washington, DC 20593-0002	

Internal

J8/R Lynch (.pdf file only)	
J8/Administration.....	2
DWA/W Whittington .....	2
DWA/M. Roberts.....	1
DMD/K. Roberts.....	1
DWAQ/G. Imhof.....	1
Library (camera ready and pdf file).....	1
Library .....	5